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LABORATORY EVALUATION OF RECYCLED HOT MIXES

(VOLUME 3)

FATIGUE RESISTANCE TO DYNAMIC LOADING

Engineering
Materials
Office

LABORATORY EVALUATION OF RECYCLED HOT MIXES (VOLUME 3)

FATIGUE RESISTANCE TO DYNAMIC LOADING

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ABSTRACT

This report summarizes the findings of a study on the evaluation and comparison of the flexural fatigue characteristics of recycled hot mixes and conventional mix. Mixtures with different recycling ratios from five projects in Ontario were evaluated using the flexural fatigue test method. The test was carried out at 21 °C under controlled strain mode, and a haversine wave loading of 0.1s duration and a 0.4s rest period was used to simulate the effect of traffic loading. The test results were presented as plots of strain ε versus the number of cycles to failure, N_f, and the estimates of fatigue coefficients were obtained from these graphs. The findings indicate that the recycled hot mixes from contracts 82-19 and 81-224 have better fatigue resistance than the conventional (HL-4, used in this investigation) mix, as measured by the laboratory tests at 21°C in terms of fatigue coefficients (k_2) using plant and laboratory mixed specimens. Recycled mixes from contracts 81-74, 82-04,and 83-43 showed no major differences in the values of k_2 as compared to the HL-4 mix.

ABRÉGÉ

Ce rapport résume les résultats d'une étude portant sur l'évaluation et la comparaison des caractéristiques de contrainte de fatigue en flexions répétées des mélanges recyclés préparés à chaud et des mélanges conventionnels. À l'aide de la méthode d'essai de contrainte de fatigue en flexions répétées, on a évalué des mélanges ayant des taux de recyclage différents et provenant de cinq projets différents en Ontario. Les essais se sont déroulés à 21°C en mode de déformation contrôlée, et on a simulé l'effet de la charge mobile avec une onde de forme 1/cosinus pendant 0,1 seconde, suivi d'une pose de 0,4 seconde. Les résultats de l'essai ont été reproduits sous forme de courbes de déformation E par rapport au nombre de cycles avant défaillance, N_f, les évaluations des coefficients de fatigue étant tirées de ces graphiques. Les résultats indiquent que les mélanges recyclés préparés à chaud des contrats 82-19 et 81-224 offrent une meilleure résistance à la fatigue que le mélange conventionnel (HL-4, utilisé pour cette évaluation), d'après des essais en laboratoire à 21°C en fonction de coefficients de fatigue (k_2) sur des échantillons mélangés en usine et en laboratoire. Les mélanges recyclés préparés à chaud des contrats 81-74, 82-04 et 83-43 ne présentent aucune différence importante de valeur k_2, avec le mélange HL-4.

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1 INTRODUCTION

Seven recycled asphalt pavement test sections, representing different regions of Ontario and covering a wide range of recycling ratios were selected to monitor the long term performance of RHM pavements. The field data based on condition survey carried out periodically on these test sections over a period of six years indicate that cracking is the major form of distress affecting the overall performance of RHM pavements. Such cracking could be the direct result of induced thermal stresses or traffic loads. The resistance to thermal cracking of recycled hot mixes from different contracts were evaluated previously and the results are given in the report [1]. The main focus of this report is on the problem of fatigue cracking due to repeated traffic loading which is different from non-load associated (thermal) cracking. The resistance to load associated fatigue cracking of asphalt materials is evaluated using beam specimens in third-point loading according to the Asphalt Institute test procedure. The following sections outline the overall objectives and the testing procedures involved in this investigation.

2 SCOPE AND OBJECTIVES

The general purpose of this study is to evaluate the relative resistance of recycled hot mixes to traffic induced fatigue cracking as compared to a conventional hot mix. More specifically, the objectives of this study can be stated as follows:

1) to review briefly the existing knowledge on fatigue cracking of asphalt mixes including the available laboratory testing procedures for fatigue characterization,
2) to select an appropriate laboratory test method and criterion for fatigue evaluation of asphaltic concrete mixes,
3) to carry out an experimental investigation for evaluating fatigue characteristics of recycled hot asphalt mixes in comparison to a conventional mix,
4) to analyse the test results and compare the performance of various recycled hot mixes with the conventional mix in terms of their potential to resist load associated fatigue cracking, and
5) to suggest improvement, if any, for future development.

3 CURRENT KNOWLEDGE ON FATIGUE CRACKING OF ASPHALT PAVEMENTS

Fatigue is the phenomenon of cracking due to a repeated induced stress or strain at levels less than the ultimate strength of the material. The load associated fatigue behaviour of paving mixtures and flexible pavement systems have been under intensive investigation for nearly four decades. These studies can be grouped into two categories, namely, a phenomenological approach and a mechanistic approach [2]. Both approaches are briefly discussed in the following sections.

3.1 PHENOMENOLOGICAL APPROACH

The phenomenological approach was initially presented by Monismith [3] and others [4,5] who attempted to simulate in the laboratory the effects of a moving load on asphalt pavements in the field. The study shows that the bottom surface of an asphalt pavement under a moving single axle load is subjected to a larger tensile strain associated with a smaller compressive strain (Figure 1). This cyclic variation of induced strain at the bottom eventually results in cracking of the bottom surface in a transverse direction. At the top surface, the strain pattern is reversed indicating the existence of a relatively smaller tensile strain of the order of one-fourth of the compressive strain [3].

Tandem axles provide a different strain pattern which may initiate cracking at the surface as a result of excessive induced tensile strain. Figure 2 shows the strain pattern in the asphaltic concrete surface course of a flexible pavement in the vicinity of a tandem axle load. It will be noted that high tensile strains were induced both at the top (in between the wheels) and the bottom (directly under the load) of the asphaltic concrete. The tensile strain at the top surface is higher than that at the bottom; as a result cracking may initiate first at the surface and progress downwards under repeated tandem axle loading [3].

Likewise the deformation in the transverse direction may also contribute to cracking as shown in Figure 3; and it is possible that transverse strain may exceed the longitudinal strain which in turn may cause longitudinal cracking before transverse cracking. However, the results of the WASHO Road Test [6] indicate that the strains parallel to the traffic are more significant. Researchers [7] have also confirmed that the strains measured on the surface of asphaltic concrete pavements under a moving single axle load and tandem axle loadings have distribution similar to that illustrated in Figures 1 and 2 respectively. As well, the available data indicated that an excellent criterion for prediction or prevention of fatigue failure is the limiting value of bending strain induced by the repeated traffic load.

In actual pavements, a reversal of bending strain occurs as a load passes over a given point on the pavement. Monismith [3] investigated the variation in strain in the longitudinal direction of a pavement as the 15,000 lb. axle load passed over a certain point of interest at a speed of 4 mph and 20 mph. Based on his study, he developed equipment [3] to simulate the reversed-bending of pavements in the field and the description of the equipment is found in reference [3]. This provided the basis for the development of a beam flexural fatigue test apparatus to characterize load associated fatigue behaviour of asphalt paving mixture. Monismith also examined [3] the effect of stress reversal in repeated flexure apparatus. He compared

the results of the reversed flexure testing (beams flexed in two directions) with those obtained for unidirectional bending (beams flexed in one direction) and concluded that stress reversal has little effect on fatigue behaviour so long as the maximum bending strains are the same in both reversed bending and unidirectional bending.

Following the work of Monismith, various kinds of fatigue test equipment have been developed for fatigue characterization of asphalt paving mixtures [8,9]. Irwin et al [10] conducted a study on the influence of different laboratory test methods on fatigue test results and recommended the third point loaded beam method in preference to others because of greater accuracy of measurement techniques and low standard error. The Asphalt Institute also selected this method for fatigue characterization. A brief description of this method is given in section 4.

3.2 MECHANISTIC APPROACH

The mechanistic approach utilizes the fracture mechanics principles to investigate damage due to fatigue cracking of paving mixtures. Researchers from Ohio State University [11] presented this approach which considers the changes in the state of stresses as a result of cracking, the geometrical and boundary conditions, the material characteristics, and its statistical variability.

In this approach, it is postulated that the fatigue life, N_f, of any material undergoes three stages: 1) crack initiation, 2) crack propagation, and 3) fracture.

Crack initiation is related to pre-existing flaws such as surface irregularities, voids, internal defects, etc.

The crack propagation is related to the fatigue life by the following equation:

$$N_f = \int_{c_0}^{c_f} \frac{1}{AK^n} dc$$

where c_0 = initial crack length (starter flow)

c_f = final crack length,

A, n = material constants,

K = stress intensity factor.

Application of this crack growth law to predict crack propagation in asphalt pavements depends on the accuracy involved in the estimation of "K". A rigorous estimation of the stress-intensity factor requires an exact solution for the cracked structure based on the linear-elastic theory. Existing theoretical values are the product of highly complex mathematical analyses for idealized model configurations and loading conditions. The obvious shortcoming of these results is that their application depends on how well the real

geometry, material, and loading conditions agree with those used in the mathematical model. In many real situations, such as pavement cracking, there is no suitable model representation for which an exact solution is available. Thus, different numerical methods for the determination of stress-intensity factors have been attempted [12]. One such widely used method is the finite element method. This method requires materials to be isotropic, homogeneous and linearly elastic, which limits their scope when a cracked multilayered pavement structure is involved. Therefore, a phenomenological approach such as the one developed by Monismith and Deacon (3,13) will be more realistic. In this case a relationship between the number of load cycles to failure of the pavement and the maximum strain will be more appropriate.

4 METHODS OF EVALUATION

The method of evaluation consisted of comparing the laboratory fatigue properties of hot recycled mixtures to that of a conventional mix. To make this comparison, asphaltic concrete beams were prepared using plant and laboratory mixes from five different recycled projects in Ontario and having various recycling ratio and rejuvenators. A standard HL-4 mix was selected to represent a conventional mix.

The Asphalt Institute procedure was selected to conduct flexural fatigue tests using beam specimens in third-point loading. The fatigue tests were conducted using MTS closed-

loop servo hydraulic testing equipment. A computer program was written to generate a sine wave displacement function, capable of applying any desired deflection at the centre of the beam sample and also to provide data output at any selected time intervals.

The relationship between maximum initial strain, ε, at the centre of the beam and the number of cycles to failure, N_f, is represented by:

$$N_f = k_1 (1/\varepsilon)^{k_2} \qquad (1)$$

where,

N_f = number of cycles to failure,

k_1 and k_2 = fatigue coefficients,

ε = initial strain measured at 200th cycle.

The above equation can be rewritten as follows:

$$\text{Log } N_f = \text{Log} k_1 - k_2 \text{ Log } \varepsilon \qquad (2)$$

$$\text{Log } \varepsilon = - \frac{1}{k_2} \text{ Log } N_f + \frac{1}{k_2} \text{ Log } k_1 \qquad (3)$$

The data are presented as plots of ε versus N_f on logarithmic scale to obtain a linear relationship. The parameter k_2 is given by the inverse of the slope of the straight line curve which is used to evaluate the fatigue resistance of asphalt paving mixes. As explained in the report [14], the higher value of k_2 indicates longer fatigue life of asphalt pavements.

5 EXPERIMENTAL PROGRAM

5.1 MIX SELECTION

For recycled hot mix specimens, plant and laboratory mixed materials from contracts 81-224, 82-19, 83-43, 81-74, and 82-04 having different recycling ratios were selected to cover the different regions in Ontario. The former were obtained directly from batch or drum plants and the latter were prepared in the laboratory using aggregates, recycled asphalt pavement materials (RAP), and asphalt cement as supplied from the field. Materials for the standard HL-4 mix (conventional mix) were selected according to the mix design procedures of the Ministry of Transportation [15].

Mix design properties of the recycled hot mix, and the site information for each test section are given in Tables 1 and 2 respectively. Numbers within the parentheses of Table 1 are the plant check results of all the contracts under investigation.

5.2 ASPHALT BINDER PROPERTIES

Extraction and recovery of the asphalt cement from the reclaimed asphalt concrete pavement and the recycled hot mix materials were carried out to characterize the binders used in each contract. Table 3 shows the binder properties of the recycled hot mixes from different contracts.

5.3 AGGREGATES

Petrographic and sieve analyses were performed on the aggregates used for all the mixes and results are given in Tables 4 and 5 respectively.

5.4 SAMPLE PREPARATION

Beam samples of 83 X 83 X 381mm length were prepared according to procedures given in ASTM D3202. The materials were compacted in two layers using kneading compaction followed by application of a static levelling load at the rate of 6.4mm/min until an applied pressure of 2760 kPa (400 psi) was reached. This pressure was maintained for a period of one minute and then released slowly. The specimen was then removed from the mould after it has cooled to room temperature and cut to the required size (76X76X381mm) using a diamond blade masonry saw.

5.6 FLEXURAL FATIGUE TEST.

Flexural fatigue tests were carried out at 21°C under controlled displacement mode to determine the fatigue resistance of the mixes to repeated loadings. A haversine wave loading of 0.1s duration and a rest period of 0.4s was used for the test. The tests were carried out under controlled strain mode because most pavement analyses use tensile strain at the bottom of asphalt layer as the failure criterion. The extreme fibre strain at the centre of the beam and the corresponding dynamic loads for every 200 cycles were recorded. The test was continued until the specimen failed and the number of cycles to

failure was recorded. The specimen is considered failed when its load carrying capacity reduces to 180N due to fatigue as a result of cyclic loading. A set of at least 6 tests were proposed at different strain levels for each specimen type such that the resulting number of load applications to fracture ranges from 3000 to 200,000 cycles. A factorial arrangement for the testing program is given in Table 6.

6 ANALYSIS OF TEST DATA

The fatigue results are presented in the form of induced bending strain versus number of load applications to failure on logarithmic scale. Figure 4, Figures 5-8, and Figures 9-13 present the fatigue results of the standard HL-4 mix, laboratory RHM, and plant RHM respectively. From these graphs the following observations can be made:

1) As predicted by the equation(3) in section 4, a linear relationship is observed between $\log\varepsilon$ and $\log N_f$ for all the mixes.
2) The correlation coefficient (R) for the best fit regression lines for $\log\varepsilon$ versus $\log N_f$ is greater than 0.97 for HL-4, laboratory RHM from contracts 82-04, 82-19, and plant RHM from 81-74. For the laboratory mix from contract 81-74, and plant mixes from 82-04 and 81-224, the correlation coefficient lies between 0.89 and 0.936. The relatively low R values of 0.76 and 0.81 were

observed for plant mixes from 82-19 and 83-43 respectively.

3) The estimated values of k_2 vary from 2.99 to 5.77 and those of k_1 vary from 1.9×10^{-05} to 2.076×10^{-13}. These values compare favourably with the results presented by Kallas and Puzinaukas [8] and Epps and Monismith [16].

4) As previously discussed in section 4, the higher value of K_2 indicates the longer fatigue life. Based on this premise, it can be seen from Table 7 that all laboratory recycled mixes with the exception of 81-74 seems to have higher fatigue resistance than the HL-4 mix. As regards the plant mixed specimens, mixes from contracts 81-74, 81-224, 82-19 have relatively higher values of k_2 than the HL-4 mix.

The findings of this study in general indicates that the resistance to fatigue cracking (as measured by the fatigue coefficients, k_2) of recycled hot mixes from contracts 82-19 and 81-224 is relatively better than that of the HL-4 mix. The rest of the recycled mixes showed no major differences in their fatigue behaviour as compared to the HL-4 mix.

6.1 VALIDITY OF TEST RESULTS

Verification of a good test or an accurate test is rather difficult because of sizeable data variation inherent in phenomenological fatigue testing. However, attempts were

made by some investigators [17,18,19] to establish a relationship between fatigue coefficients which could provide a basis for comparison of fatigue tests conducted by various researchers. Consequently, Pell [17] and others [18,19] found a linear relationship between k_2 and $\log k_1$ in the form of

$$k_2 = A*\log k_1 + C \qquad (4)$$

This relationship between k_2 and $\log k_1$ indicates that the $\log\varepsilon$-$\log N_f$ lines as expressed by the equation (2) tend to initiate from a common intersection point. This implies that as induced tensile (bending) strains increase the differences among fatigue lives of various mixes will decrease. Presented in Figure 14 is the linear relationship between k_2 and $\log k_1$ as determined from the experimental data which seems to indicate that the fatigue test results obtained in this study are comparable to those of the other investigators[20].

7 CONCLUSIONS RECOMMENDATIONS

7.1 CONCLUSIONS

Based on the investigation carried out in this project, the following conclusions can be made:

1) The test results show that recycled mixes from contracts 82-19 and 81-224 have higher k_2 values (indicative of higher fatigue resistance) than the HL-4 mix.

3) Recycled mixes from the rest of the contracts (81-74, 82-04,and 83-43) showed no major differences in the values of k_2 as compared to the HL-4 mix.

3) The fatigue performance of asphalt mixes can be characterized by a strain-fatigue life relation of the form:

$$N_f = k_1 (1/\varepsilon)^{k_2}$$

where,

N_f = number of cycles to failure,

k_1 and k_2 = fatigue coefficients,

ε = initial strain measured at 200th cycle.

4) Linear relationship was obtained between k_2 and $\log k_1$ as observed by various investigators [17,18,19].

7.2 RECOMMENDATIONS

1) Investigate the effects of stress reversal (i.e reversed-bending) on fatigue life. This is important because in actual pavements in the field, a reversal of bending strain occurs under moving wheel loads [3].

2) Study the influence of temperature on fatigue coefficients, k_1 and k_2, and the fatigue life,

particularly at low temperatures (e.g. 4°C) for the recycled hot mixes.

3) Establish relationship between mix variables (binder content, void content, viscosity etc.) and fatigue characteristics.

4) Modify the computer program to conduct the fatigue test under controlled strain mode as measured by the LVDT instead of the actuator of the MTS equipment.

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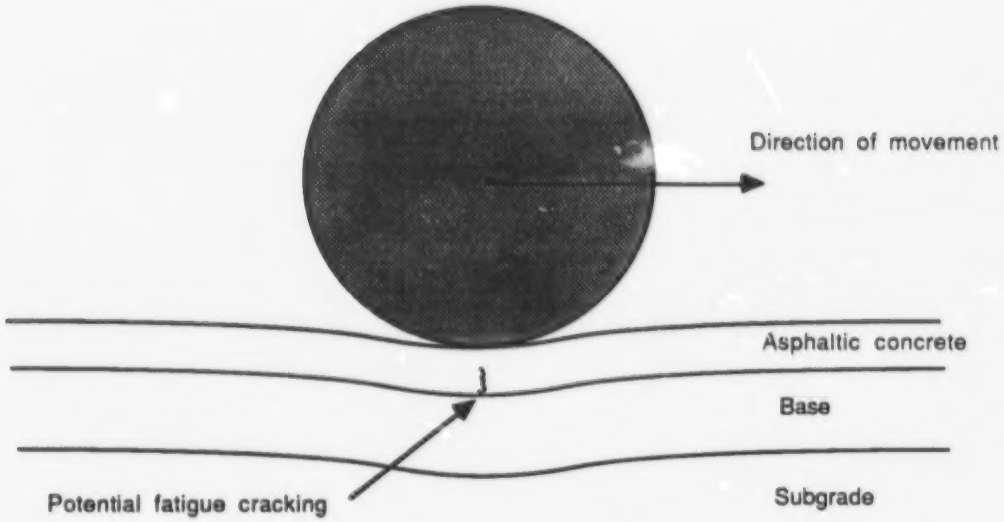

Figure 1a Deformation of asphaltic concrete under single axle load

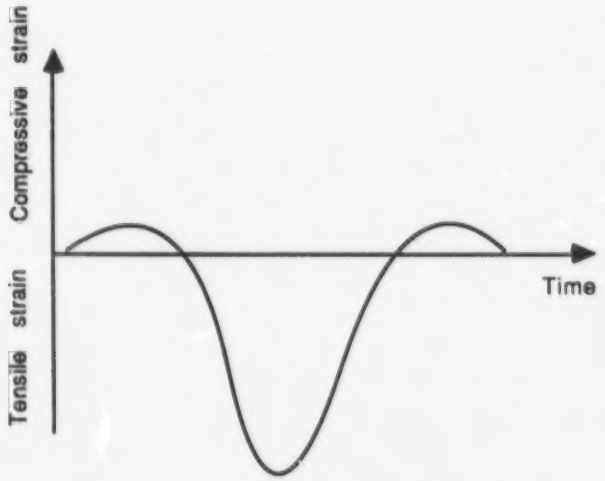

Figure 1b Longitudinal variation of strain in bottom of asphaltic concrete surface under single axle load

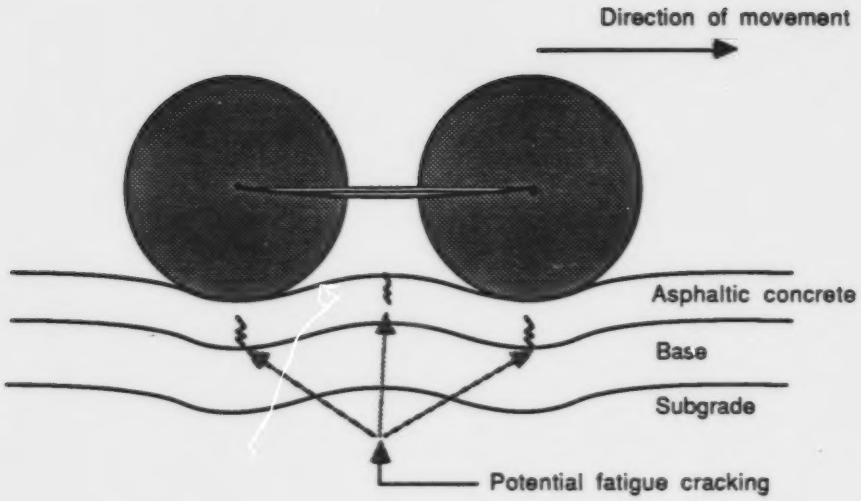

Figure 2a Deformation of asphaltic concrete under tandem axle load

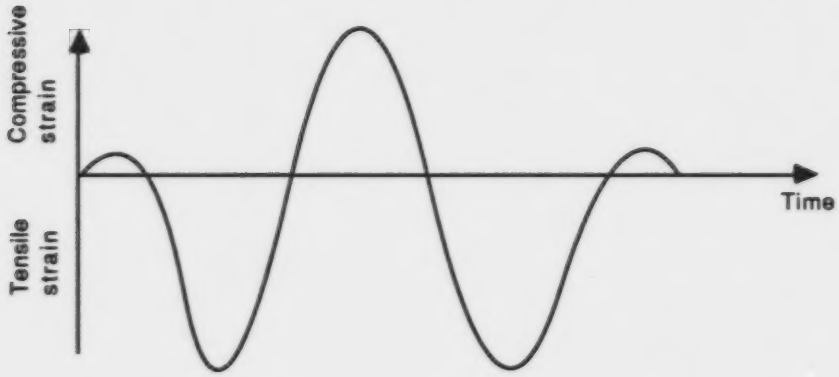

Figure 2b Longitudinal strain distribution in bottom of asphaltic concrete surface under tandem axle load

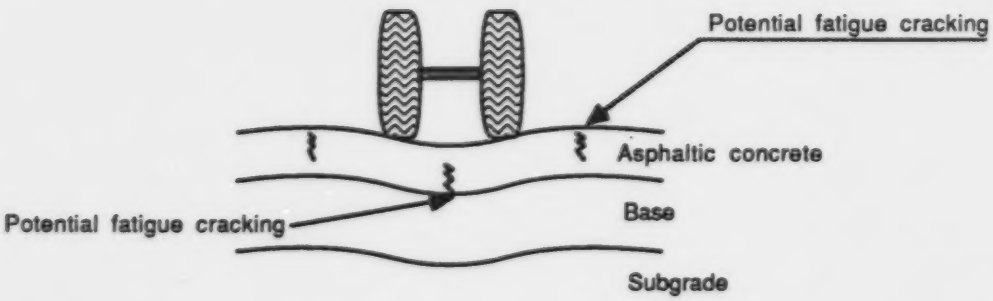

Figure 3 Transverse deformation of asphaltic concrete under dual tires

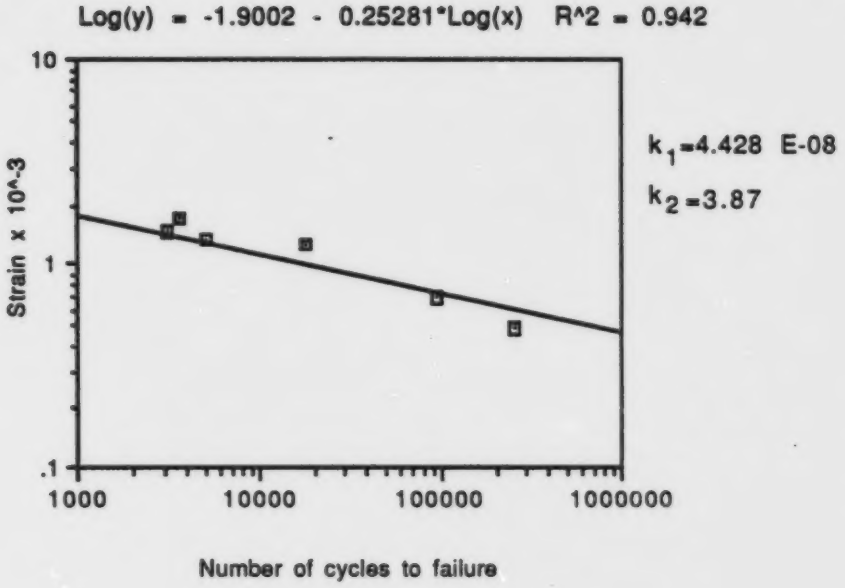

Figure 4 Strain-fatigue life results for HL4

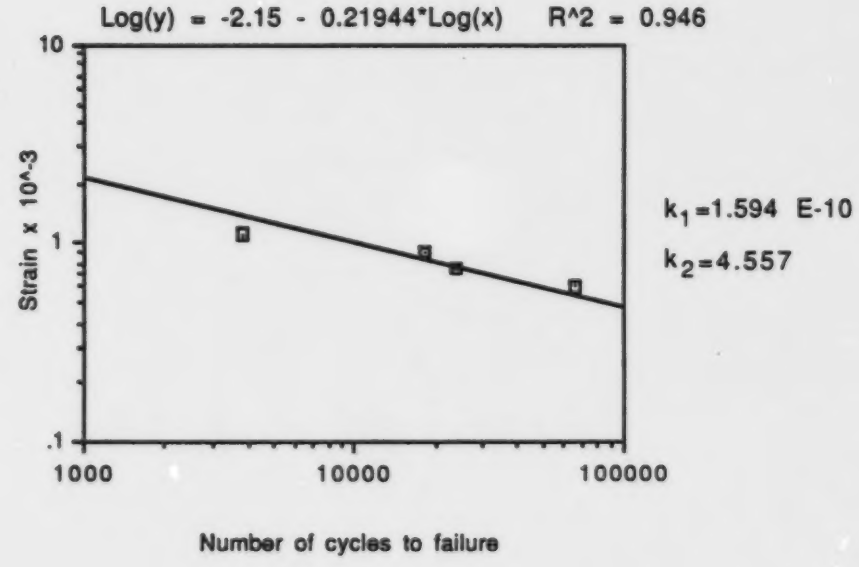

Figure 5 Strain-fatigue life results for 82-04L

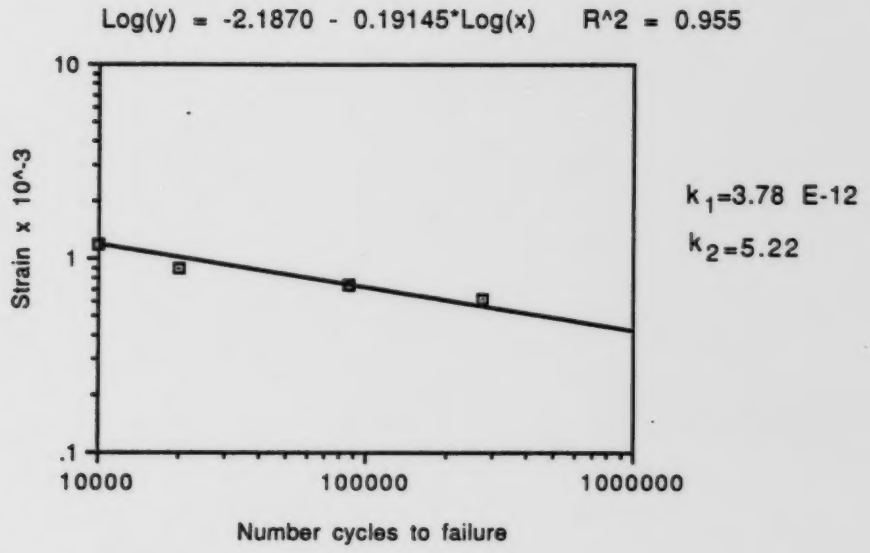

Figure 6 Strain-fatigue life results for 82-19L

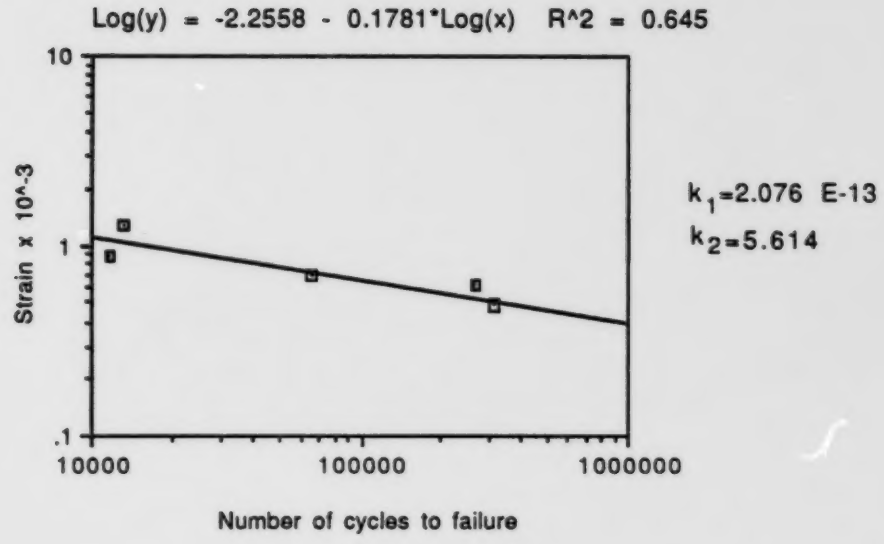

Figure 7 Strain-fatigue life results for 81-224L

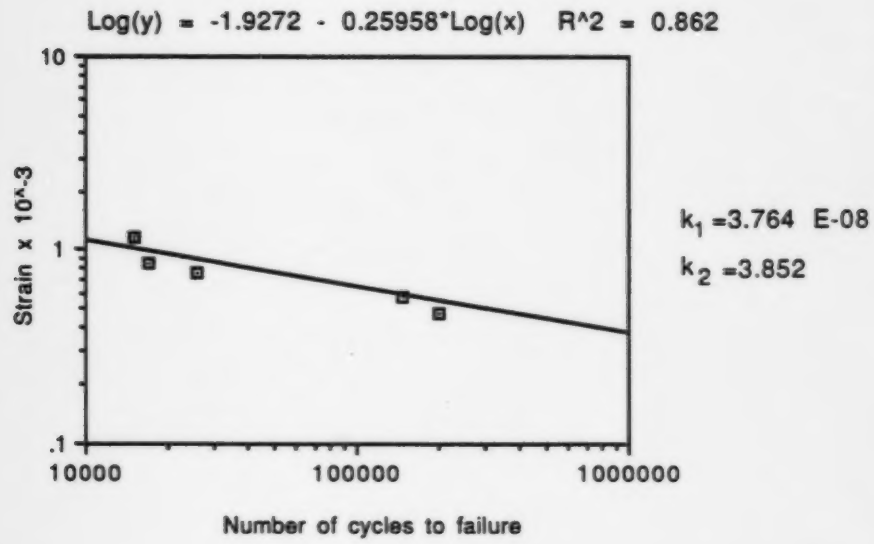

Figure 8 Strain-fatigue life results for 81-74L

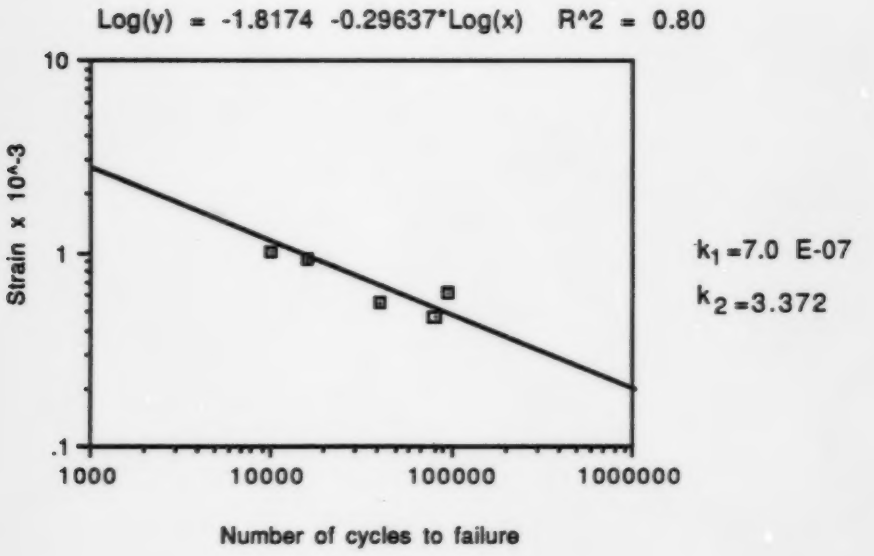

Figure 9 Strain-fatigue life results for 82-04P

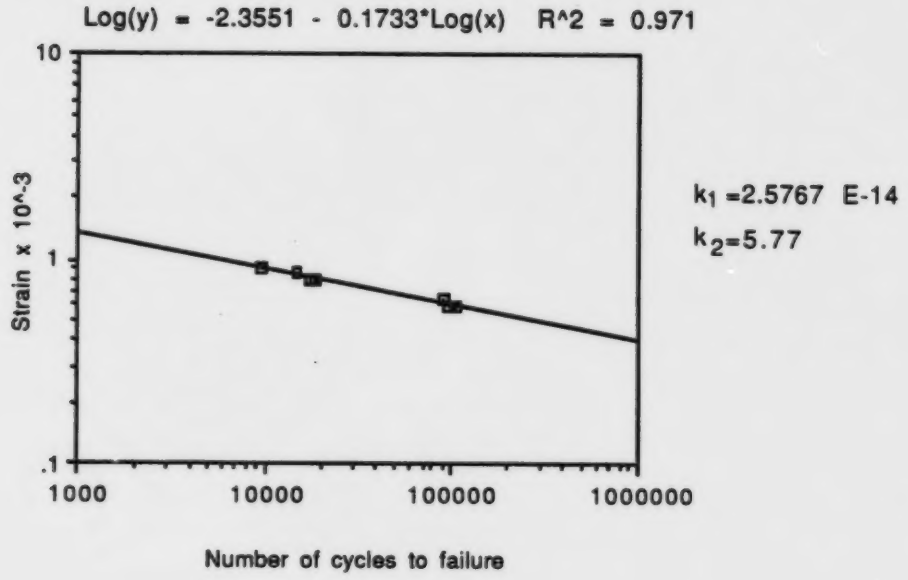

Figure 10 Strain-fatigue life results for 81-74P

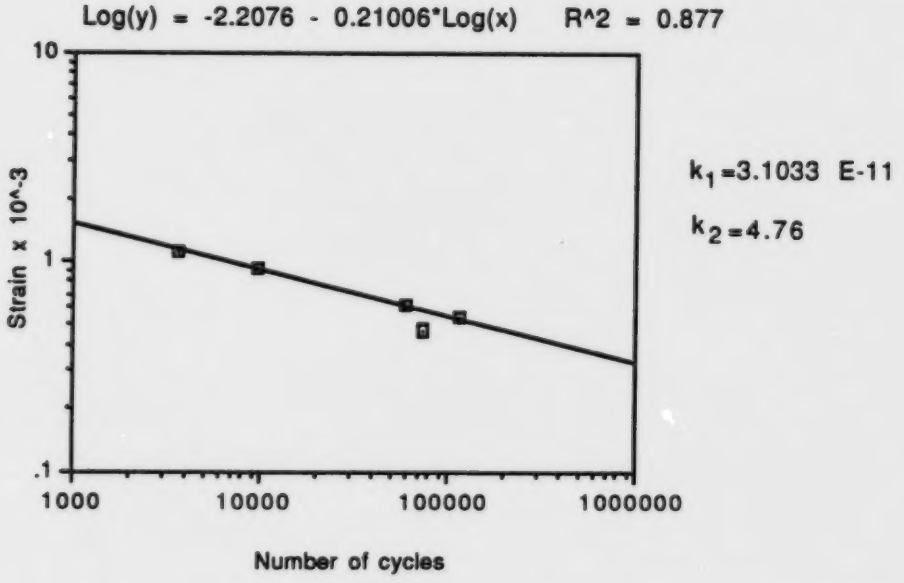

Figure 11 Strain-fatigue life results for 81-224P

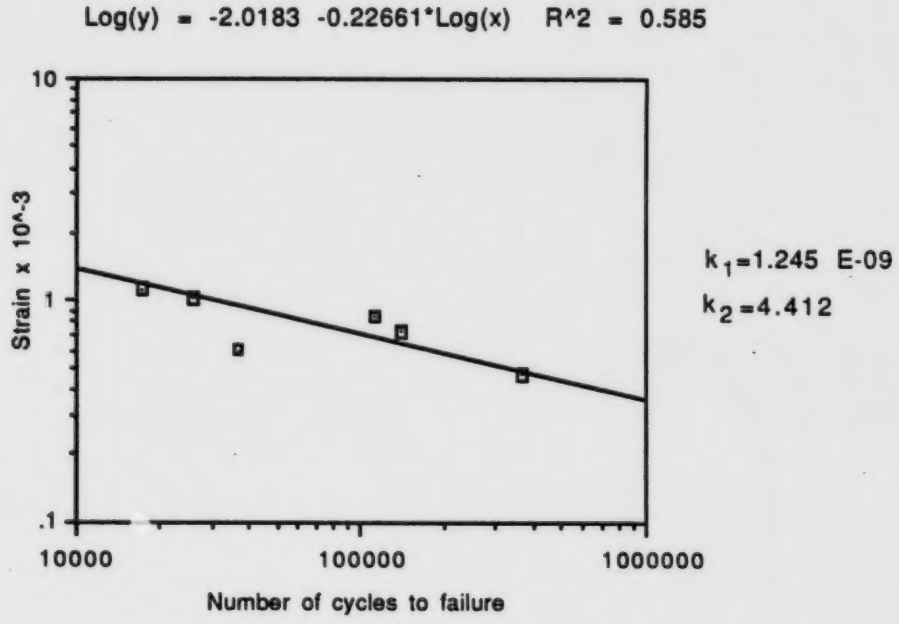

Figure 12 Strain-fatigue life results for 82-19P

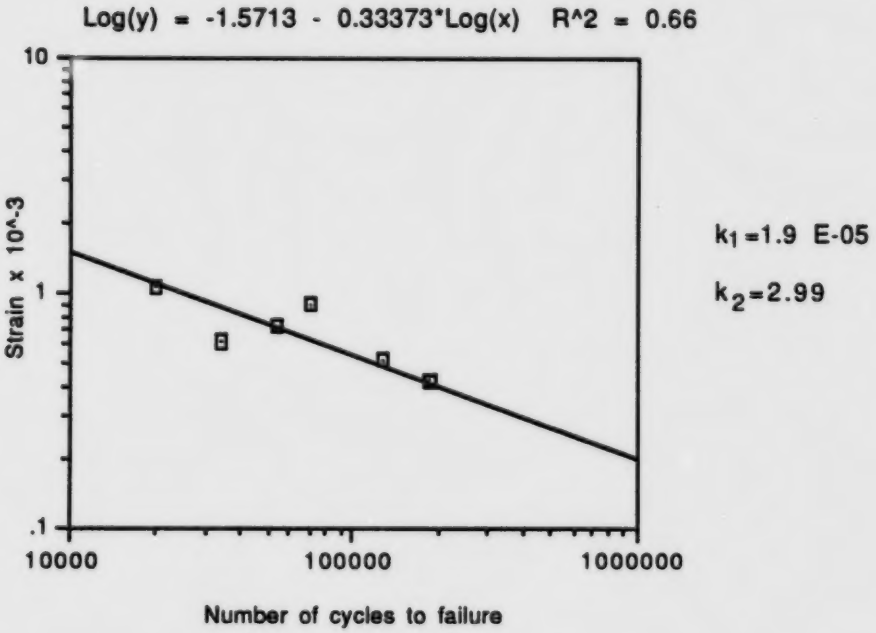

Figure 13 Strain-fatigue life results for 83-43P

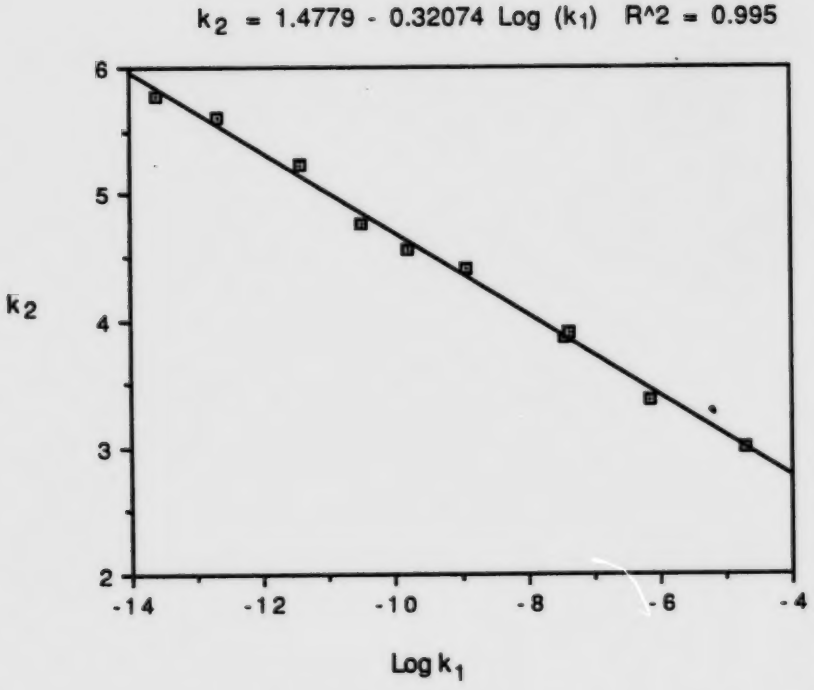

Figure 14 Relationship between k_2 and Log k_1

Table 1: Mix Design Properties of Recycled Hot Mixes and HL4 Mix

CONTRACT NUMBER	RECYCLING RATIO	ASPHALT CEMENT, %			Stability N	Flow	VMA %	Ret., % 4.75mm	Air Voids %
		ADDED	TOTAL	PEN					
81-224	60/40	2.7	5.2	300/400	10,000 (16,887)	9.2 (11.4)	N/A (14.6)	40	2.8 (1.4)
82-19	30/70	4.5	5.3	150/200	10,000 (12,080)	13.5 (14.2)	12.5 (14.3)	45	1.6 (1.0)
82-60	60/40	3.2	5.6	B.P.500	10,000 (10,346)	8.8 (8.8)	15.0 (15.0)	40	3.0 (3.3)
81-74	50/50	2.3*	5.0	300/400	16,760 (14,469)	12.5 (12.1)	N/A (14.8)	45	2.8 (2.8)
82-04	70/30	1.7	5.3	150/200	16,280 (17,658)	13.8 (13.5)	15.6 (15.3)	36	3.0 (1.9)
83-07	50/50	2.6	5.1	B.P.500	7,800 (10,884)	9.0 (11.4)	14.0 (13.9)	39	3.0 (1.5)
83-43	25/75 (DFC)	3.8	5.3	85/100	23,000 (24,042)	18.1 (17.4)	11.8 (9.5)	45	2.7 (2.6)
HL4	-	-	5.3	85/100	13600	10.4	13.8	45	4.0

* 0.5% antistripping agent added

Plant check results are given in parentheses

Table 2: AADT for Different RHM Test Sections

CONTRACT	REGION	HWY	LOCATION	YEAR					
				81	82	83	84	85	86
81-224	NORTH WESTERN	11	30km East of HWY633	600	550	550	500	500	500
82-19	CENTRAL	649	10km N. of Bobcaygeon	1000	1000	1000	950	950	950
82-60	EASTERN	62	2km N. of combermere			1250	1350	1350	1450
81-74	EASTERN	60	35km East of Renfrew	1500	1500	1500	1350	1350	1450
82-04	SOUTH WESTERN	21	5km S. of Thamesville	1900	2100	2100	2100	2100	2100
83-07	SOUTH WESTERN	2	6km W. of Thamesville			4600	4300	3600	3600
83-43	CENTRAL	QEW	Niag. Falls	26,200	26,000	28,200	30,000	32,150	33,400

Table 3 Recovered Asphalt Binder Properties of RHM

Contract	RAP		RHM	
	Pen @25°C mm	K. Visc. @ 135°C mm^2/sec	Pen @25°C mm	K. Visc. @ 135°C mm^2/sec
81-74	35	1073	53	457
81-224	31	517	57	326
82-04	28	508	36	498
82-19	20	1456	63	401
83-43	22	1167	30*	708*

* Recovered one year after construction

Table 4 Aggregate Description for Various Mixes

Mix Identification	Description	
	CA	FA
81-74	Crushed gravel containing Palaeo-zoic carbonates and marble granite	Silica rich natural sand
81-224	Crushed igneous gravel with mainly granite and granite gneiss	Silica rich natural sand
82-04	Crushed carbonate gravel with < 10% granite and gneiss	Silica rich natural sand
82-19	Crushed limestone gravel	Carbonate & silicate natural sand
83-43	Steel slag (DOFASCO)	Steel slag (DOFASCO)
HL-4	95% carbonate rock, 5% granite	95% carbonate rock, 5% granite

Table 5 Aggregate Gradations for HL4 and RHM Mixes

Sieve size			mm								μm			
			19	16	13.2	9.5	6.7	4.75	2.36	1.18	600	300	150	75
HL4	% Retained	CA			23.2	68.5	89.0	98.1	98.3	98.5	98.7	98.8	99.0	99.2
		FA						1.0	20.1	39.0	58.6	82.4	92.4	96.7
		Final			10.5	31.0	40.3	45.0	55.5	65.9	76.7	89.8	95.4	97.8
81-74	% Retained	RAP			3.2	13.4	26.0	36.8	50.7	60.9	71.5	84.1	91.0	94.8
		CA		4.3	20.4	63.7	88.3	92.7	93.6	94.5	95.4	96.2	97.1	98.0
		FA						0.4	1.4	5.3	21.0	60.6	88.8	95.9
		Final		1.3	7.5	25.1	38.4	45.0	52.2	58.3	67.2	82.4	92.3	96.0
81-224	% Retained	RAP		1.3	5.8	24.0	38.9	49.0	62.4	72.9	81.2	87.6	91.7	94.9
		CA		2.8	17.2	55.7	81.6	94.6	95.2	95.7	96.3	96.9	97.4	98.0
		FA					1.0	9.1	29.4	51.3	72.2	87.8	95.1	97.9
		BLSA	0.5	1.0	1.6	3.6	5.7	8.3	17.1	32.2	55.8	85.3	97.5	99.4
		Final		1.0	4.9	19.6	31.2	40.0	52.6	94.9	77.0	88.1	93.7	96.4
82-04	% Retained	RAP	2.0	4.0	7.0	18.0	33.0	44.2	57.0	64.0	71.0	84.0	93.0	95.5
		CA		0.3	8.5	59.9	88.7	98.1	98.3	98.6	98.8	98.0	89.3	99.5
		FA				0.5	1.0	2.0	4.1	8.0	14.5	33.9	81.7	94.2
		Final	1.4	2.8	5.3	15.6	27.5	36.0	45.4	51.2	57.8	71.8	90.4	95.4
82-19	% Retained	RAP	1.3	6.7	10.0	23.0	34.7	45.0	59.7	70.3	79.0	87.0	93.0	96.0
		CA		3.5	19.5	63.4	88.5	97.6	97.9	98.2	98.5	98.8	99.1	99.0
		FA						1.9	16.4	35.1	51.5	70.2	83.1	91.1
		BLSA				1.4	2.9	5.3	12.3	24.1	39.8	65.6	88.5	96.1
		Final	0.4	3.1	9.0	26.8	38.3	45.0	53.7	62.9	71.9	83.1	92.1	96.2
83-43	% Retained	RAP			1.0	8.0	22.0	32.0	46.0	58.0	68.0	80.0	89.0	92.8
		CA			2.0	34.6	69.7	94.5	95.2	95.9	96.7	97.4	98.1	98.8
		FA							39.1	62.4	75.4	85.0	91.1	95.2
		Final			1.0	15.6	32.8	45.0	62.9	74.6	92.2	88.7	93.4	96.0

Table 6 Experimental Design for Flexural Fatigue Tests

Mix		Vertical deflection, mm		
		0.12-0.18	0.18-0.24	0.24-0.30
81-74	Plant	2	2	2
	Lab	2	2	2
81-224	Plant	2	2	2
	Lab	2	2	2
82-04	Plant	2	2	2
	Lab	2	2	2
82-19	Plant	2	2	2
	Lab	2	2	2
83-43	Plant	2	2	2
	Lab	*	*	*
HL4	Lab	2	2	2

Note:- Two samples per cell

* = No samples

Table 7 Fatigue Coefficients for Various Mixes

Mix Type	k_2	k_1
HL4	3.87	4.428 E-08
82-04L	4.557	1.594 E-10
82-19L	5.22	3.78 E-12
81-224L	5.614	2.076 E-13
81-74L	3.852	3.764 E-08
82-04P	3.372	7.0 E-07
81-74P	5.77	2.577 E-14
81-224P	4.76	3.10 E-11
82-19P	4.412	1.245 E-09
83-43P	2.99	1.9 E-05